

Stabilising Lyme Regis – a strategic approach

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Abstract

Coastal erosion and landslides have been a constant threat to Lyme Regis for over 250 years. In the past, ad hoc coast protection and slope stabilisation works were carried out to repair failures of existing structures and damage caused by storms and landslide events. By the 1980s, the frequency and scale of coastal erosion and land instability had reached a point whereby the local coastal protection authority, West Dorset District Council, realised that a change in approach was needed to secure the long-term future of the town. The Lyme Regis Environmental Improvements initiative was developed from the late 1980s to provide a strategic and integrated programme of coast protection and cliff stabilisation measures designed to mitigate the increasing threat of climate change, coastal erosion and landslides, whilst respecting the site's unique heritage and environmental interests. This paper outlines the background and principal phases of the project which have been successfully delivered over the period 1990-2015.

Keywords

Key words: slopes - stabilisation, coastal engineering, environment

1. Introduction

The historic coastal town of Lyme Regis is situated in one of the most unstable geological settings in the UK and has suffered severely from the effects of coastal erosion and landsliding. Over the years, landslide activity and cliff retreat has damaged or destroyed many properties throughout the town together with roads, land and infrastructure. In the absence of engineering intervention the future for the town was bleak with existing coast protection structures reaching the end of their useful life, landslide activity increasing in response to climate change, sea-level rise and a higher frequency of wet winters over the last two decades.

In order to secure the future of Lyme Regis, West Dorset District Council has, since the late 1980s, promoted a long-term programme of phased investigations and engineering schemes to protect and stabilise the coastal frontage of the town. This approach has enabled the Council to be proactive in identifying and dealing with coastal defence, cliff erosion and landslide problems in a strategic manner, rather than reacting to land instability and storm events once they have occurred. Central to the success of this strategy has been extensive long-term consultations with the local community and other stakeholders.

This paper aims to illustrate how long-term persistence and vision in tackling severe coastal instability problems can be successful and have substantial benefits to the community and local environment despite the considerable challenges involved.

2. Historical background

Lyme Regis is located on an actively-eroding soft rock coastline in southern England with much of the town being constructed on old coastal landslides in Lower Jurassic clays and mudstones of the Blue Lias and Charmouth Mudstone Formations. These cliffs are subject to continuous slow movements and, from time to time, destructive landslide activity. Historically, the town was a major port with the original nucleus of the town centred on the River Lym and the harbour located 0.5km to the south-west (Figure 1). The harbour breakwater, known as the Cobb (possibly from the Welsh word “cob” meaning “embankment”), is considered to be the oldest working breakwater of its type in the UK with the original structure dating back at least to the 13th century.

The original mediaeval town is thought to have extended a considerable distance into what is now the sea. Other than the Cobb, major seawalls in the older parts of the town were not constructed until the 1750s with the seawall between the town centre and the harbour not completed until the 1860s. Where unprotected, the coastline continued to retreat due to a combination of marine erosion and associated landsliding; the materials eroded from the cliffs do not afford much protection in the form of beach-forming materials as the lithology is mostly fine grained. Even in those locations where seawalls were constructed, the landslide systems in the steep and unstable coastal slopes behind continued to retreat inland, causing considerable damage.

The traditional approach to dealing with coastal defence and cliff instability tended to comprise isolated responses to a particular landslide or seawall failure. Previous attempts to stabilise these landslides were not always successful, essentially because the landslide extents and mechanisms were not well understood at that time.

Coastal erosion and landsliding, whilst causing considerable difficulties in the built-up areas of the town, also have some positive aspects. The spectacular scenery on the coasts adjacent to the town is a result of the continuing erosion which also yields abundant fossils. These attractions have meant that tourism is now the town's principal industry. The importance of the area in terms of geology and geomorphology is recognised internationally through the designation of a UNESCO Natural World Heritage Site, commonly known as the “Jurassic Coast”.

3. Strategy

Since the late 1980s, West Dorset District Council has promoted a long-term programme of engineering projects covering the whole of the frontage at Lyme Regis, all within an overarching coastal management strategy. The objective of the strategy has been to provide the town with long-term protection against coastal erosion, landsliding and storms, together with improvements to both the natural and built environments.

The main feature of the strategy was the consideration of the entire landslide system and coastal area of Lyme Regis as a whole. This is in contrast to the traditional piecemeal and reactive approach that often only considers isolated sites or areas which happen to be problematic at the time. The area of interest extended from the top of the coastal slope down to the sea cliffs, intertidal zone and seabed about 1km offshore as well as coastal areas to the west and east of Lyme Regis. Extensive multidisciplinary investigations both detailed and wide in scope were carried out within this area in order to address the relatively complex nature of the coastal erosion and cliff instability problems.

The programme was split into three main phases (Section 5), with each phase typically comprising a range of investigation work and engineering schemes, including:

- Desk studies
- Geomorphological and geological mapping of the cliffs, landslides and beaches
- Phased ground investigations with installation of ground instrumentation and monitoring
- Preparation of conceptual ground models and process models for the cliffs and beaches
- Local emergency works
- Full engineering schemes to stabilise and protect the coastal areas of the town
- Ongoing extensive consultations with residents, the local community and other stakeholders.

This holistic, long-term, proactive approach is considered to have many benefits (Brunsden and Moore 1999; Cole et al. 2002; Moore and Davis 2014; Moore et al. 2010), in particular:

- the economic case that prevention is better than having to deal with the emergency response and aftermath of destructive erosion or landsliding
- allows time and investment to establish a detailed understanding of the problems through phased investigations
- allows prioritisation of works for complex sites in order of urgency
- a phased approach avoids excessive disruption to wide areas of the town
- delivers economies of scale - the cost of considering the town's coastline as a whole under a single strategy being less than attempting to deal with individual problem sites in isolation, and

- ensures that schemes are concordant with marine and landslide processes operating on adjacent sections of coastline.

4 Investigations

A wide range of multidisciplinary investigations was carried out in several stages over many years with the findings of the early investigations informing the design of later ones. The main types of investigation and their value are summarised in Table 1. The main findings of the investigations were fundamental to the design and development of coast protection and cliff stabilisation schemes, including:

- That much of town has been built on pre-existing landslides which were active when climatic conditions were worse than at present, for example in late glacial times and during the mediaeval “little ice age”. The landslide systems extend up to 500m inland from the high watermark, which was much further than appreciated previously.
- The landslides are large, complex, multilayered systems, strongly controlled by geological structure and faulting within the Lower Jurassic clays and mudstones.
- The existing landslides were prone to rapid reactivation and expansion in the present-day due to a combination of marine erosion at the toe, foreshore lowering and the increasing frequency of wet winters.
- The beaches fronting the town were a small fraction of their former extent, and their size and protective effect has been diminished due to a combination of artificial and natural effects, principally the occurrence of large landslides to the south-west of the town blocking south eastwards longshore drift.
- Exacerbated by loss of the beaches, there has been continuing marine erosion at the toe of the landslide systems together with lowering of foreshore ledges.
- The existing coast protection structures were deteriorating, with many approaching the end of their useful life.
- The town’s drainage systems were in a poor state, with leakage tending to increase groundwater levels which promote instability.
- In the absence of any engineering intervention the very future of the town was under threat, and large parts of it could have been destroyed relatively rapidly as a result of coastal erosion and landsliding.

5 Development of schemes

The findings of the investigations indicated that the only realistic way of safeguarding the long-term future of the town was through the implementation of heavy civil engineering schemes to reduce the risk of destructive erosion and landsliding. In the “do nothing” scenario, it was likely that landslide activity would have spread rapidly into the densely built

up area of the town and hence there was good justification for the implementation of engineering schemes both socially and in terms of government economic criteria. Adaptation to coastal change through managed retreat was not a realistic option. In order to limit the amount of disruption in the town at any one time, but also to allow sufficient time for investigations and the design of relatively complex engineering schemes, the project was undertaken in a series of phases in order of urgency and within the long-term strategic programme. Such was the degree of threat from landsliding it was recognised that there may not be sufficient time to develop and implement schemes before another destructive landslide event took place. Local, small-scale, emergency works were therefore carried out in critical areas in order to provide sufficient time for the development of a full scheme.

These typically comprised:

- Repairs to drainage.
- Local beach replenishment.
- Temporary stabilising bored piles with a short design life of 10 years.
- Local areas of stabilising bored piles, which would be incorporated into a main scheme in due course.

In addition, a landslide warning system was set up to give alerts of the onset of potentially damaging ground movement, linked to in situ ground monitoring instrumentation. This was analogous to the Environment Agency's flood warning system.

The proposed works involved substantial changes to the physical characteristics of the beach and frontage which are the most popular and sensitive areas of the town, together with construction on private land, in roads and in public gardens. Consultation therefore played a key role in the development of schemes (Davis and Cole, 2002). The two most valuable methods of encouraging public participation were the establishment of a design office within the town, which the public were encouraged to visit, and regular meetings of a coastal forum. These meetings were chaired by the Mayor of Lyme Regis and set up specifically to allow townspeople to have a direct input into the development of scheme options. High levels of involvement from the public and stakeholders minimised potential conflict, producing a sense of public ownership and high level of consensus across the town. Elements of the scheme taken forward for detailed design were typically determined from a long list of potential ideas, many of which were put forward by the public. Ideas taken forward were subject to appraisal and screening in terms of environmental impact, technical merit and costs.

The development and construction of all phases was funded principally from grant in aid funding under the Coastal Protection Act 1949 from the Department for Environment and Rural Affairs (Defra) through the Environment Agency (EA) with major contributions from West Dorset District Council, South West Water as the local water utilities company and Dorset County Council as highway authority.

There were many challenges which had a strong influence on the planning and implementation of schemes, in particular:

- Ensuring that schemes would be effective technically but would also be compatible with the local historical and natural environments, and with the expectations of the local community.
- Physical constraints on access and the need to work on potentially unstable slopes, often requiring the use of light plant and rope access techniques.
- Avoiding excessive disruption to the town, particularly during busy holiday seasons.

The schemes were constructed in three major phases (Table 2):

Phase I (constructed 1993-1995)

This phase comprised a new seawall along the central eastern area of the town adjacent to the River Lym. The coast protection function was to provide a new line of defence against coastal erosion in front of the historical masonry seawalls which were around 250 years old and in a dilapidated state. The new seawall incorporates holding tanks and a pumping station, to pump the town's sewage inland for treatment instead of being discharge untreated into the sea. The scheme also provided a new promenade which was later to be used by heavy vehicles to access the construction site for Phase IV (Figure 2).

Phases II & III (constructed 2005-2007)

This phase (Fort et al 2007) comprised a new seawall, sand and shingle beaches, beach control structures and extensive slope stabilisation works (comprising bored piles, earthworks and drainage) located in the main frontage and tourist area of the town (Figure 3 and 4). Phase III was intended to tackle instability problems on the western flank of the town but was found to be uneconomic; however some elements of merit were incorporated within the Phase II scheme. The main challenges of this scheme were plant weight and ground condition restrictions on working in order to maintain stability of slopes and difficult access through steep slopes, narrow streets and individual plots of private land. The scheme provided a sandy beach as well as shingle beach coast protection in order to preserve and enhance an important attraction for tourists.

Phase IV (constructed 2013-2015)

This was the last in the series of major schemes. It is located on the east flank of Lyme Regis and comprises a new seawall in front of the existing dilapidated wall (Dales et al 2014) and extensive slope stabilisation works (Candian et al 2015, Daskalopoulos 2015) including soil nails, drainage and piling (Figures 5 and 6). Coastal erosion and landsliding on the eastern part of town are of critical importance to the geological and biodiversity value of this World Heritage

Site and as such had to be reconciled with conflicting requirements to protect people, property and infrastructure. This balance was achieved by adopting an overall design concept where stabilisation works prevented the expansion of destructive landslides inland by constructing a barrier of stabilised ground, rather than stabilising all the areas of existing landslides. This had the benefit that the greater part of the landslides and the most environmentally sensitive areas of the coastline were left untouched, thereby allowing continuing erosion and avoiding unacceptable environmental impacts. The scheme included a comprehensive mitigation strategy to minimise adverse effects on the environment, and to improve and enhance the natural habitats and geological exposures. The landscaping and environmental mitigation works conceal nearly all of the extensive geotechnical engineering works from view (Figure 7). One of the main challenges in this phase was working in an area of active landslides, which required careful monitoring of ground movements. Despite the huge challenges, the construction work delivered an outstanding safety record, with no reportable incidents from a workforce of 561 and 174,960 manhours worked.

6 Project achievements

The overall project has been successful, securing the long-term future of Lyme Regis in the face of a considerable and growing threat from aggressive coastal erosion and landsliding in one of the most unstable geological settings in the UK. Engineering solutions were delivered without any further destructive landslide events taking place, through a strategic programme of works in order of urgency, with the use of local emergency works where necessary. In addition, the Phase IV construction works were completed safely within an area of active landsliding through one of the most extreme UK winters on record (2013-2014) both in terms of prolonged heavy rainfall and sea state.

The project achieved a successful balance between engineering requirements, the needs of the local community and environmental issues to the extent that all of the component schemes have been well received from a grateful community and environmental stakeholders alike. It has played a large part in maintaining and enhancing the vibrancy and confidence of the town, encouraging private investment and making a positive difference to the day-to-day lives of ordinary people whose properties and businesses were at risk. Substantial spin-off benefits have been provided in terms of bathing waters quality, improvements to amenity and safe public access along the town's frontage. A journalist from a local newspaper wrote (Boothroyd 2014), *"I love engineers. They're logical, methodical, business-like and attentive to detail – for physical and material forces are unforgiving of sloppiness, and one small technical error in an engineering project can be catastrophic. There's no ego and no waffle; they calmly analyse, plan and do it. Yet they're also imaginative and adaptable as circumstances change, and easy to work with. What a shame it is that, as a country, we tend in our public life not to promote the values and qualities of the engineer. How lucky we are in Lyme they've done us proud."*

The various schemes have won a plethora of industry awards and accolades that attest the achievements of Lyme Regis Environmental Improvements Programme (Table 3)

7 Lessons learned

The strategic, long-term approach was found to have many benefits in addition to the economic case that prevention is better than cure. For example, considering the whole of the Lyme Regis coastline as part of the strategy yielded a deeper understanding of land instability and coastal erosion mechanisms than could have been gained from the study of isolated problem areas alone. It also allowed the determination of the very best coast protection management options and the optimum programme for their implementation.

The direct involvement of the public and stakeholders in the development of schemes over many years was an essential part of the strategy, and a big contributor to the success and popularity of the schemes. However, the practical implementation of construction works needed to be carefully managed to avoid excessive disruption to the busy town with difficult site access. If poorly planned and managed, the construction works themselves could have been so disruptive and damaging to the town that public support would have been lost.

On the technical side, the design of the stabilisation works was found to be critically dependent on the fine detail of the geology and geomorphology, such as positions of small faults and individual thin strata. A detailed conceptual ground model (Sellwood et al 2000), built up through several stages of ground investigation, was an essential basis for the design of an effective engineering scheme. As such, the use of geomorphological techniques (Brunsden 2002) formed a continuous thread throughout the implementation of the project, from identifying the nature and extent of the problem in the first place, assessing the consequences of doing nothing, informing the business case and through to the detailed design of the stabilisation works. The ground conditions encountered during construction were found to be very close to the conceptual ground models developed during the investigation stages.

Lastly, there is often a rather pessimistic attitude from some quarters that, however hard the engineering community works on protecting a town from coastal erosion, it is ultimately doomed to failure because “it’s unsustainable” and “nature will always win in the end”. However, the Lyme Regis project has demonstrated that it is possible to protect town against natural processes while still enhancing the natural environment. The project may be thought of as the latest in a long line of schemes since construction of the Cobb, which together have maintained the viability of the town for at least the last 800 years.

8 CONCLUSION

It is considered that there would be great benefits in using the coastal instability and erosion management methodologies applied to the Lyme Regis scheme in future projects facing similar challenges. There are many locations in the UK and internationally where coastal erosion and landsliding in soft rock cliffs are threatening communities and where there are also considerable environmental constraints and opportunities. Employing the philosophies outlined in this paper could make the difference between protecting a community and allowing a town to be destroyed by natural processes.

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Figures

- Figure 1 Aerial photograph of Lyme Regis showing the location of main construction phases. The boundaries for Phases II and IV coincide with the landslide geomorphology.
- Figure 2 Phase I seawall and promenade with the sewage pumping station in the background.
- Figure 3 Aerial photograph of the Phase II works shown the construction of a new seawall, piles, earthworks, drainage, and sand and shingle beach replenishment.

- Figure 4 Schematic block diagram showing main methods of stabilisation at Phase II
- Figure 5 Aerial photograph showing the key features of Phase IV.
- Figure 6 Types of construction at Phase IV: a) concrete seawall, b) soil nailing, c) 300mm dowel piles, d) 900mm anchored piles, e) ground anchor installation. *(We propose that that these are arranged into a series of small “thumbnails”.)*
- Figure 7 An aerial view the Phase IV seawall, showing the preservation of geomorphological features and geological outcrops above.

Tables

- Table 1 The main types of investigation used at Lyme Regis.
- Table 2 The three main engineering phases with their challenges and benefits.
- Table 3 Industry awards